Homeostasis for dummies

by a dummy

2026-01-26

Physiology, feedbacks, homeostasis

As we have seen, organisms, and the chemical reactions that comprise them, work best within a range of temperatures, beyond which stuff goes poorly. This is also true of all sorts of other internal conditions (e.g., pH, O_2 concentrations, salinity) and concentrations of biologically relevant nutrients (e.g., ATP) and signaling molecules (e.g., hormones, neurotransmitters). Consider water balance: organisms that are overhydrated have low solute concentrations that cause problems. Cells might even burst! On the other hand, with too little water blood becomes viscous and solute concentrations in cells can be so high they interfere with biochemical reactions. In short, a whole suite of conditions need to be kept within a more or less narrow range that permits the organism to function. Enter **homeostasis**, the tendency towards a region of stable or desired conditions. Or, more precisely,:

> "a self-regulating process by which biological systems maintain stability while adjusting to changing external conditions" — Billman 2020[1]

Think of it this way: There is some **range of acceptable conditions** (and within that a range that might be preferable). The organism "wants"[2] to keep its internal conditions within these ranges. To do so there need to be **processes that push/pull the conditions back within those ranges**, but also some mechanisms for activating those mechanisms at the right times. That is, the organism needs **information and**

[1] Homeostasis: the underappreciated and far too often ignored central organizing principle of physiology. Frontiers in Physiology 11:200.

[2] With scare quotes because this is a cheap short-hand. We do not know what an organism wants in most cases, nor is an organism necessarily consciously aware of its internal condition. (How is *your* pH doing? Is it good?) . Rather, there are benefits to having internal conditions within some range. That's really what I mean. But "want" is much shorter to write!

feedbacks to turn on the mechanisms at the right time and then to turn them off, like a thermostat keeping the temperature in your room comfortable. While it sounds simple, conceptually, that involves an awful lot of physiology! And behavior, too!

Let's make a general list of ways an organism like a guinea pig might achieve, say, a comfortable body temperature:

- pant
- put fur on on end / fluff up fur
- find shade / sun
- sploot[3]
- find / avoid wind
- get wet / stay dry
- shunt blood to periphery / core
- shiver
- burn ATP in brown fat
- grow thicker fur / shed
- move to a new habitat

[3] 

And the list goes on.

We might be starting to see some patterns. Animals can either avoid the bad, or deal with it. The responses might be rapid or longer-term. In fact, why don't you place the responses we listed on these axes (Figure 1)?

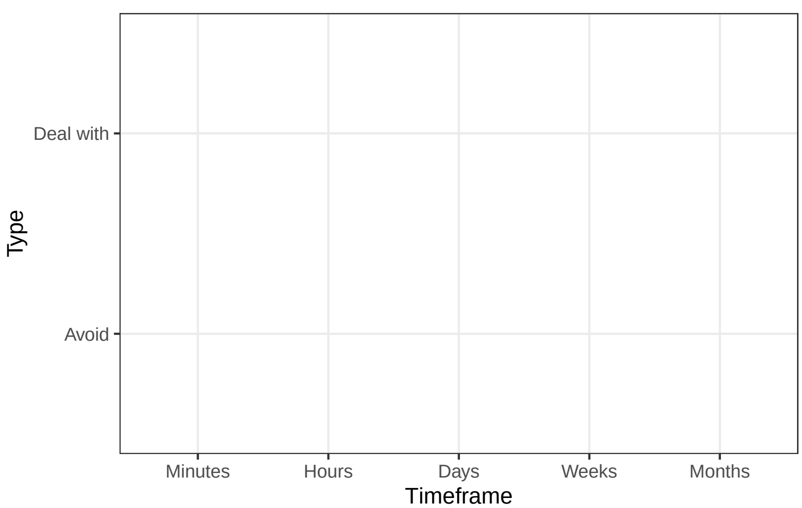

Figure 1

Avoiding the bad

The conditions we observe and record may not be those experienced by the organism. Animals can seek out thermal conditions that are relatively better for them, either in space or time. This seems obvious with a tiny bit of thought. There are micro-habitats that differ in temperature from the average. A kangaroo rat (*Dipodomys* spp.) that lives in the Sonoran desert rarely experiences the hottest daytime temperatures that environment has to offer—it hides underground, especially in the heat of the day—nor does a polar bear typically experience the coldest temperatures of the arctic—again, hiding or hibernating[4] during the winter. Habitats are often full of refugia from climatic extremes!

[4] A note about **hibernation, brumation, estivation**, and the like: these are complex phenomena that involve behavioral and physiological changes *in anticipation* of poor conditions. And what's more, they are usually tied to a lack of resources—food or water—rather than to warm or cold periods. Another strategy in response to the same anticipation of deteriorating conditions is to migrate. There are all sorts of ways animals avoid the bad.

Yet we often make broad generalizations about how temperature (or similar conditions) affect organisms out in the environment. For instance, we the abidance of weather stations, cheap-ish data loggers, and removing sensing to provide granular (e.g., daily, hourly) data on the temperature and humidity over broad swaths of the Earth. And then we think about, for instance, where in that landscape of temperature and humidity (and other things) our organism of interesting might survive, grow, reproduce, and flourish. Those of us crazy enough to study the ecology of ticks (e.g., *Ixodes scapularis*, which vector the agents of Lyme disease and other nasty infections) continually make this mistake. I, for instance, placed ticks in little soil core enclosures in forests in the Northeast, along with temperature loggers, for a winter. I expected to see the overwintering ticks die when it got really cold—lab studies show that at low temperatures they are prone to freeze if they so much as touch an ice crystal—but what I saw instead is that the ups and downs of temperature I measured in those cores had *nothing* to do with their survival. They were somehow avoiding the cold and ice, carrying along merrily.

This isn't to say that animals are not influenced by prevailing conditions—the temperatures in the nooks and crannies are determined, to a large extent, by the prevailing conditions. Rather, just remember that the conditions an animal experiences may not be the conditions you expect or observe.

Dealing with the bad

Even when they do experience the poor conditions, they are far from passive. In the short term we might see animals shiver or sweat, change their activity levels, pant, and so on. Inside their bodies even more is going on that I will leave for a physiology class.

Over a bit longer period of time we see even more and different sorts of changes. It turns out that organisms often have multiple, slightly different versions of many key genes that function better at different temperatures. Remember those thermal-performance curves we have seen? Imagine a bunch of those, just shifted to hotter or colder temperatures. Animals can express different versions in response to differences in, say, temperature. So you know how people say they need to acclimate to conditions when they move from a cold place to a warm one, or vice versa? Well, that's real! It does take a week or two for your body to **acclimate** (or acclimatize[5]) to the heat. The same is true for acclimating to high altitudes, too! This is a way for organisms to deal with challenging conditions that occur over longer stretches of time.

[5] There are these two words that mean slightly different things, only the difference depends on who you ask and where you look. So in this class we'll use them interchangeably.

Over even longer stretches of time, generations and generations, we will see **adaptation** to challenging, prevailing conditions. As a region warms up, say, individuals that do a bit better in warm conditions—survive, grow, and reproduce better—will tend to leave more offspring than their neighbors who were barely making it through the heat waves. Assuming the traits that help them function in warmer conditions (e.g., different protein variants) are heritable, then the population will be a bit different in the next generation, full of individuals who are, like their parents, generally better in warm conditions. Repeat over and over and you see evolution by natural selection at work, a population with a different distribution of traits than we started with. Indeed, there are already examples of animals evolving in response to climate change, such as Caribbean lizards adapting to repeated hurricanes.

Consequences

So, what to make of all of this acclimation and adaption? First, I think it is worth noting that these responses to conditions, like temperature, highlight just how important they are! I mean, you don't see large numbers of physiological and behavioral responses to the partial pressure of nitrogen, do you? But temperature? Oh yes, we see lots and lots of ways that organisms cope with high and low temperatures!

Second, it is important to be cautious about extrapolating from mean temperatures, precipitation, and similar. I mean, yes, these give you a very good approximation of the conditions that organisms face in a particular place and time, like the Palouse in October. Remember the Whitaker diagram? It works because these first-order approximations are really, really helpful. But when you zoom in just a bit you see that the world is actually much more heterogeneous, full of nooks and crannies with different temperatures and humidity and so on. Some animals might be thriving in these little pockets of refuge both in space and time. Thus, be careful when interpreting range maps or considering where a species can or cannot live[6].

[6] More on this later!

Third, remember that homeostasis is a *process*. Organisms are constantly responding to challenging conditions, and that is totally normal. For instance, researchers often take elevated levels of gluccocorticoid or "stress" hormones as evidence that their study organisms are "stressed out" and thus, presumably, doing poorly. But as any physiologist worth their salt will remind you, this is actually evidence that the organism is *responding* to some challenge, perhaps quite well, thank you! The problems come about when those stress hormones do not return to a reasonable baseline.